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Team 10: Joint Dynamic Allocation of Fires and Sensors (JDAFS) Joint Starting Conditions Analysis

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TEAM 10 MEMBERS

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INTRODUCTION

Joint starting conditions (JSC) are the generated set of initial conditions that are provided a combat model for its use within a study or analysis. These conditions include such data as starting Blue and Red common operational pictures (COPs), starting unit locations, starting unit statuses (force strength/attrition effects and current logistics state), etc. A particular scenario provides the context and the JSC apply to a specific starting point within that scenario (e.g., Day D+27). Currently JSC development is executed primarily using Subject Matter Expert (SME) input, discussion, and adjudication for spreadsheet tools and separate attrition and Intelligence, Surveillance, and Reconnaissance (ISR) models. The results are often not repeatable and can be driven by dominant personalities.

As part of the TRADOC Analysis Center's (TRAC's) structured scenario development process, the Joint Dynamic Allocation of Fires and Sensors (JDAFS) model is being reviewed as a tool to support JSC data development. JDAFS is a discrete event simulation that accounts for first-order combat effects using Army approved algorithms. It couples the dynamic, optimized allocation of resources (such as unmanned platforms and artillery assets) to a simulation in order to render better representations of network-enabled warfare. The process to use JDAFS has four main points of effort. First, identify the full range of stating conditions and associated factors that must be accounted for in the JSC process. Second, identify those JSC data that can be developed using model and simulation (M&S) support - clearly capturing and recognizing the interaction between M&S data and non-M&S supported data. Third, identify and execute appropriate M&S enhancements to support JSC data development. Fourth, develop an appropriate Design of Experiment (DOE) front end to support sensitivity analysis and alternative starting conditions.

APPROACH TO JOINT STARTING CONDITIONS

When using high-resolution ground combat simulations, scenarios often do not start running in these high-resolution simulations on D-day. For instance, if the high-resolution starts on D+10, then initial conditions for the high-resolution simulations must be developed. The process for setting these initial conditions often has relied on a single ISR expert to determine detection and identification percentages. Then, an air campaign expert determines the destruction percentage and dispersion of remaining enemy assets throughout the area of operation. This overall process is difficult to defend to an analysis review board which brings into question the results of the high-resolution runs due to the lack of traceability to certifiable algorithms and experimental performance data when setting these initial conditions. A repeatable, traceable process that is approved by the scenario, intelligence, threats, and Joint community is desired.

High-Resolution simulations use the JSC data to represent the intelligence preparation of the battlefield that all military units perform prior to major operations. By providing a traceable methodology of determining these initial starting conditions, the high-resolution simulations, which are already traceable and whose results are well accepted by senior military leaders, can provide defendable results to senior military decision makers.

The goals of Team #10 were:

- Refine and test a Joint battlespace shaping scenario that represents ISR asset allocation/trade-offs and kinetic effects in JDAFS.
- Develop a data farming interface (or at least requirements for one) that lends itself to analyst ease-of-use and provides a range of potential starting conditions.
- Identify and define appropriate improvements to JDAFS to better represent joint shaping assets and that result in traceable realistic Joint Starting Conditions for high-resolution ground combat simulations.

JDAFS

The JDAFS simulation is a publicly available, discrete event simulation that accounts for first order combat effects using Army-approved algorithms. It couples the dynamic allocation of resources, such as unmanned platforms and artillery assets, to a simulation to render better representations of network enabled warfare. The United States Army TRADOC Analysis Center has supported the development of JDAFS for the past several years.

JDAFS implements an entity-level, "low-resolution" approach to simulation modeling. Units are not modeled to the level of detail present in high-resolution models such as COMBATXXI. Algorithms, such as for detection and adjudication of weapons effects, are designed to capture first-

order effects without the time-consuming detail present in the high-resolution models.

The starting condition input parameters that the high-resolution simulations require fall into three categories: unit, geographical and operating environment parameters. The problem of determining appropriate JSC is one of determining these parameters following an initial phase of the battle just prior to the operation of real interest. Therefore, traditional analysis with one, or a relatively few, number of output measures is not a good fit to this problem.

This output from this effort is different than the output that is typically obtained from a combat simulation in that it is the end state rather than measures of performance of entities within the simulation that is desired. It is important that a range of starting conditions is available so that expert judgment can be used to determine whether the follow-on, high-resolution simulation runs should begin with a best-case, a worst-case, or an average case situation.

The base-case approach taken was to identify some key measures and perform a simple frequency analysis on the results. For each measure, three output conditions were identified. These corresponded to the "best," "worst," and "most likely" cases. Specifically, the 25th, 50th, and 75th percentile runs are identified based on the frequency distribution of the measure, and these correspond to the "best," "most likely," and "worst" cases respectively.

DESCRIPTION OF SCENARIO

The scenario consisted of Blue, Red, and Neutral (Civilian) units. Blue assets included ground, air, and surface (Navy) units. Red assets included ground and air defense units. A notional display of the force locations at the start of the scenario is shown in Figure 1.

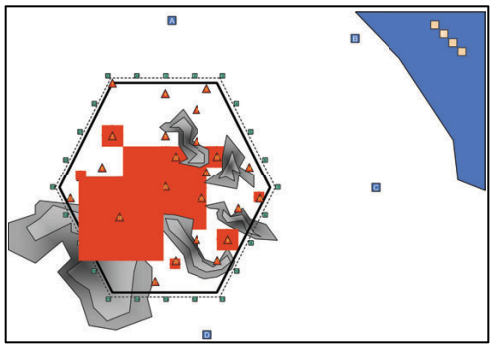

Figure 1: Joint Starting Conditions Scenario

A snapshot of the base case scenario implemented in JDAFS at the beginning of the run is shown in Figure 2. Red and Blue units are shown in their respective colors, while circles represent Civilian units.

The unit positions at the end of one replication are shown in Figure 3. The X's represent casualties.

Design of Experiments

In order to facilitate the execution of multiple scenarios according to an experimental design, a modular approach was developed. Two databases were processed by a Java program that generated the JDAFS input databases, as shown in Figure 4.

The Template database consists of a complete base-case scenario for JDAFS. The Design database consists of two tables. One identifies the factors in the Template database by table, column, and an optional value. The second table points to the particular designs, based on the quantity of parameters varied in the DOE.

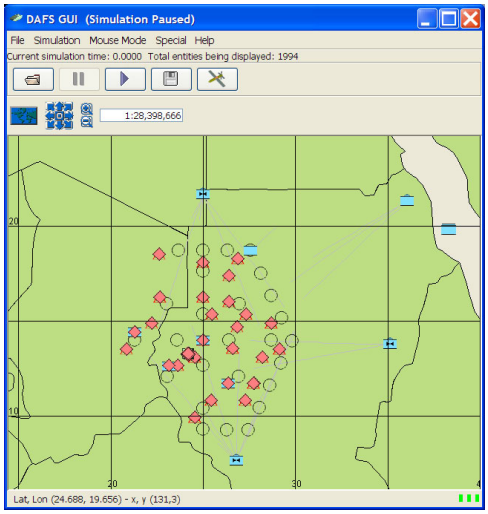

Figure 2: Joint Starting Conditions Scenario in JDAFS

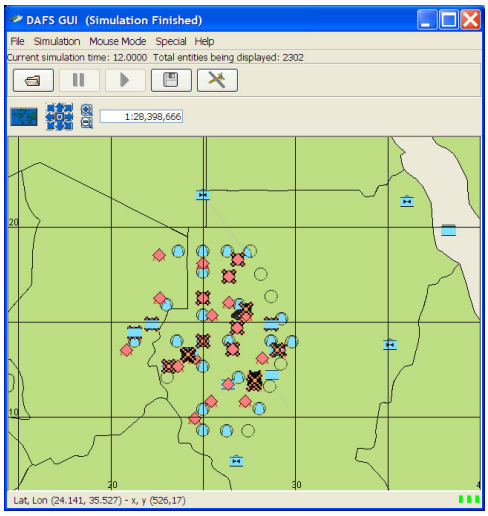

Figure 3: Base Case Scenario at End of Replication

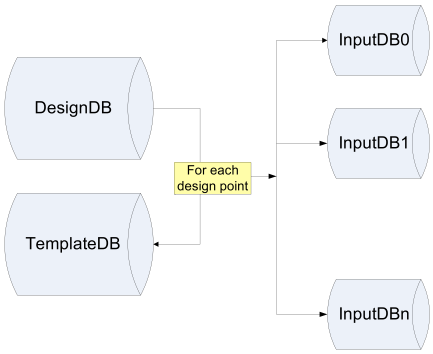

Figure 4: Generation of Input Databases

RESULTS AND ANALYSIS

Analysis of Base Case

As noted above, setting joint starting conditions does not lend itself to traditional analysis, since there are no Measures of Effectiveness (MOEs) that are ultimately of interest. Rather, the outputs of interest consist of the possible JSCs for the next phase of the operation. Thus, the outputs are highly multivariate, consisting of all unit positions, dispositions, and strengths as well as the perception of the enemy. That is, the output is a COP for the enemy and/or friendly forces.

The base case was replicated independently 100 times for the initial analysis. The measures chosen to examine were Blue casualties and Red casualties. The distribution of Blue casualties is shown in Figure 5. The distribution shows nothing particularly unusual. The mode is 8, occurring in 21 out of 100 scenarios.

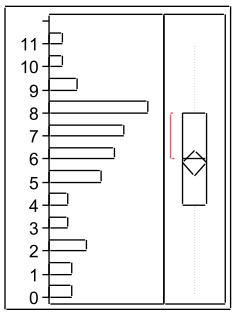

Figure 5: Distribution of Blue Casualties

The distribution of Red casualties is shown in Figure 6. This shows an interesting bimodal pattern. Although the mode is between 500 and 550 casualties, there are also many that were between 50 and 100.

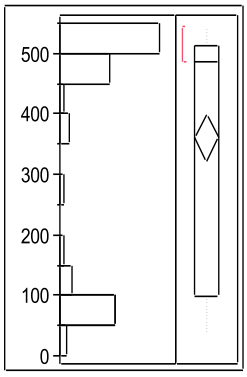

Figure 6: Distribution of Red Casualties

Examining the frequency of casualties by percentile is another way to identify scenarios of interest. This is shown in Table 1, which identifies the 0.25. 0.50, and 0.75 percentile replications. Additionally, the replication is captured so that the results for that condition can be traced.

Percentile	Blue Casualties (Replication)	Red Casualties (Replication)
0.25	4 (17)	98 (95)
0.50	6 (94)	234 (41)
0.75	8 (52)	511 (79)

Table 1: Percentiles of Casualties by Side

Design of Experiments

An experimental design was run with seven factors, three being the optimization intervals (used by the model to set the frequency of optimization for use by the fires, sensor, and unmanned scheduling algorithms) within JDAFS, and the remaining four being the maximum Electro-Optical (EO) sensor ranges for four different Blue platforms. This resulted in 17 design points, each of which had 30 replications. Each replication took approximately 2 minutes on a laptop computer, and the entire set of runs was executed overnight. In a high-performance computing environment (i.e., a cluster) the turnaround time would have been quite rapid.

SUMMARY OF FINDINGS

The analysis of the previous section could be used to identify a small set of representative or interesting scenarios for the next phase of the study. That is, the ending conditions of the JDAFS replication corresponding to the given scenarios would be used to set the JSCs for the next model's runs. Currently, it is straightforward to convert these dispositions into starting conditions for more runs using JDAFS. Thus, JDAFS could be a valuable tool for a panel of subject matter experts in adjudicating possibilities. This would be an improvement over the current approach

Several future improvements to the JDAFS simulation to better represent the setting of JSC were identified. These improvements included:

- Better representation of stand-off ISR missions.
- Implement enemy detection states (positional, functional).
- Better representation of aircraft refueling.
- Capability for units to first become available later in the simulation run.
- Initial Intelligence Preparation of the Battlefield for the JDAFS simulation run.
- Further refine Generalized DOE Interface.
- Finalize an input method to execute multiple DOE configurations.
- Merge output files into a common database to facilitate follow-on analysis.
- Execute final version of the joint starting conditions scenario.

Further Work

JDAFS shows great promise as a tool to enhance the setting of joint starting conditions. In addition to additional JDAFS function improvements, further work includes finalizing and testing the DOE capabilities and refining the user interface. Improved automation of output analysis is also desirable, especially formatting the output reports to be more amenable for use by statistical packages.